

Application of S-GTO Power Modules

AEPS Review

by

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November 5, 2002

PRESENTATION OUTLINE

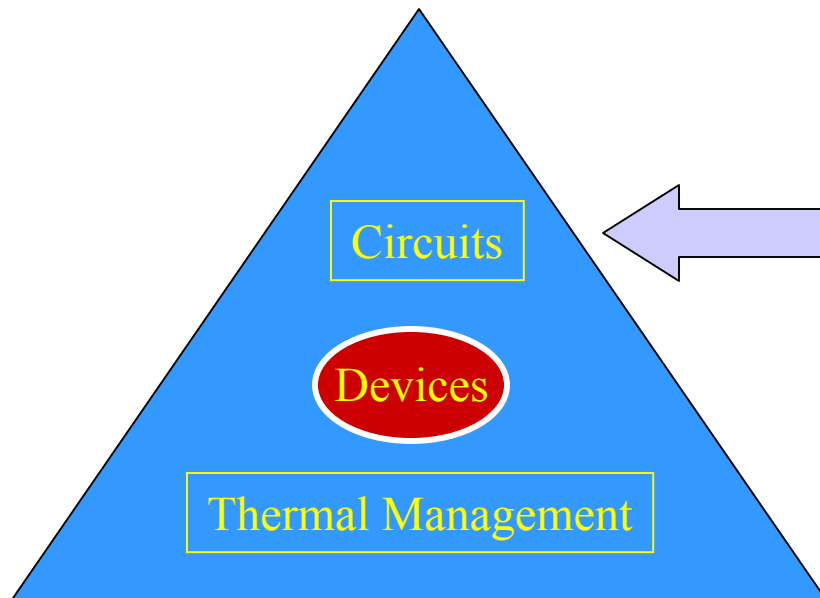
- **Corporate Overview**
- **S-GTO Technology**
- **Applications Overview**
- **Future Applications**

CORPORATE OVERVIEW

Our Mission



‘To Serve the Global Power Market with Leading Edge Electronic Systems and Components Offering Optimum Value and Quality to Our Customers’



Key Ingredients:

- Semiconductor devices
- Control & auxiliary circuits
- Thermal management packaging

Applications:

- Power conditioning
- Conversion

Corporate Facilities



Exton, PA

Area: 50,000 sq. feet



Malvern, PA

Area: 30,000 sq. feet



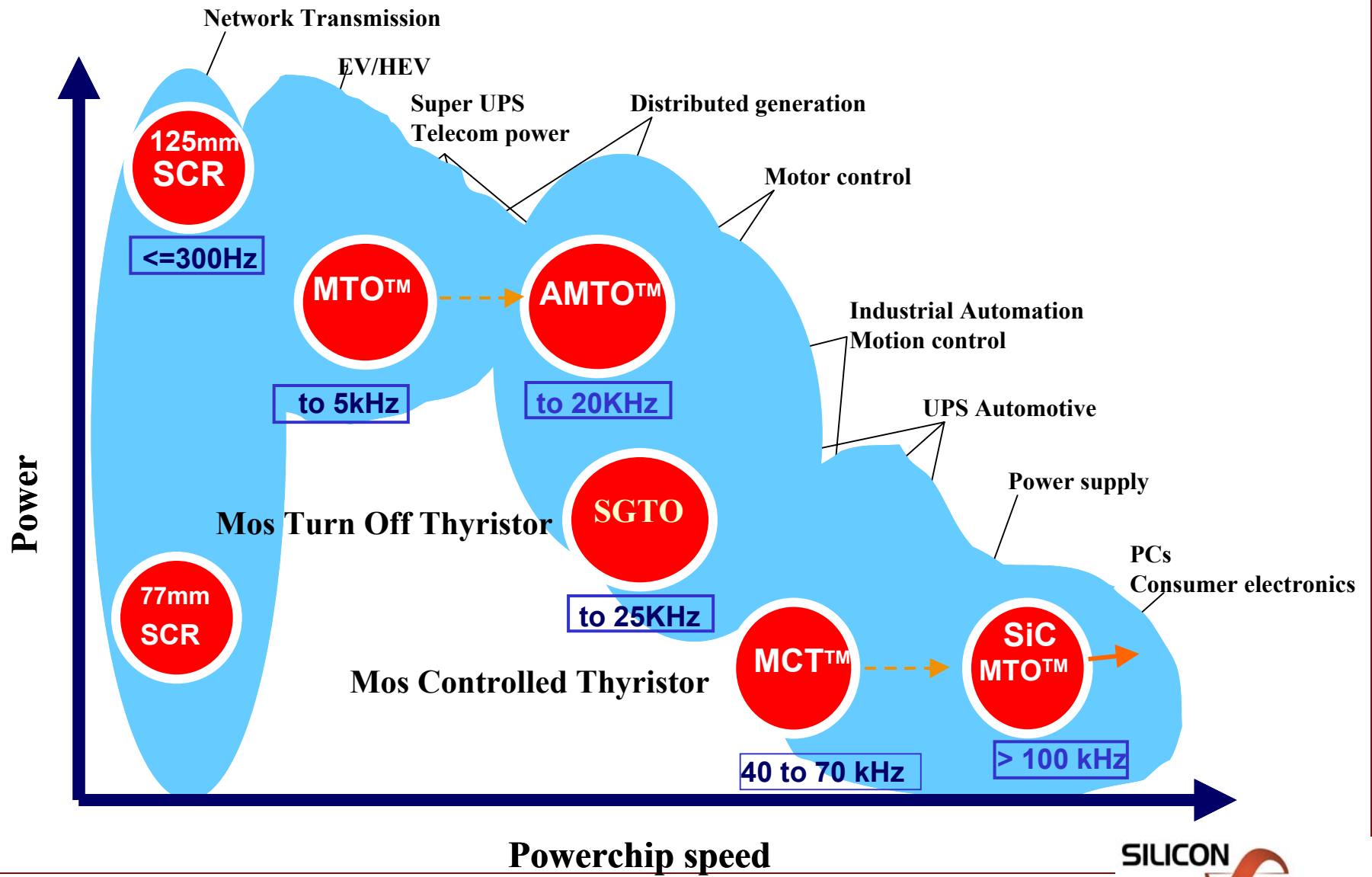
Latham, NY

Area: 16,000 sq. feet



SILICON  **POWER**

Powerchip Hierarchy & the Mid-power Market



Source: The Huber Mills power report, published by GuilderGroup, 3/2000.

11/4/02

Vertically Integrated

Static Switches



• Power Quality Systems

- Static Transfer Switches
- Statcom/UPS
- Static Voltage Regulators
- STS/PDUs
- Power Processors



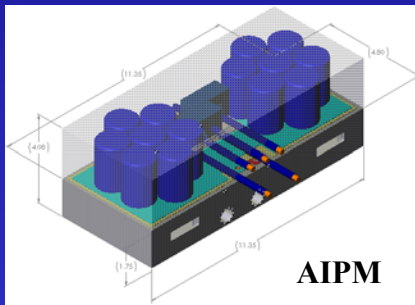
WPM



LSS Technology

• Power Quality Component/Devices

- SCR & Diodes
- LSS Devices
- MTO's
- MCT's
- SGTO's
- WPM's
- Avalanche Photo Diodes



AIPM

• Power Quality R&D

- Modular power processor development
- Current Limiting Switching Modules
- Ultra Fast LV Switches

CUSTOMERS

ABB



Rockwell
Electronic Controls and Communications

APC
Legendary Reliability™

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We bring good things to life.

FMC

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INDUCTOTHERM

INDUCTOTHERM

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MORE AND MORE PEOPLE NEED ALSTOM



APPLIED MATERIALS®

THE INFORMATION AGE STARTS HERE™

SILICON
A stylized orange and red graphic resembling a flame or a drop.
POWER

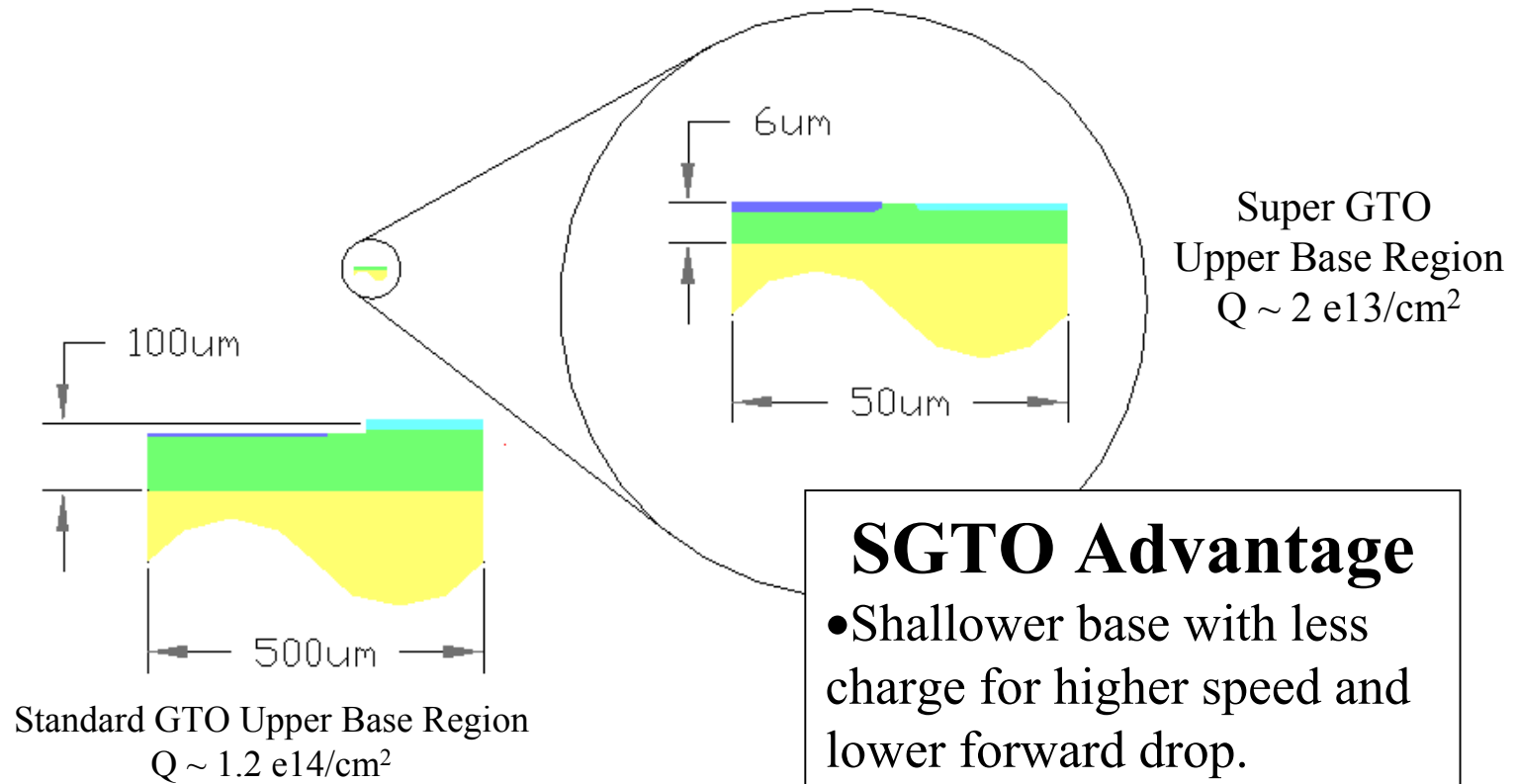
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“SUPER” GTO TECHNOLOGY

S-GTO: Intro

- GTO thyristor fabricated using planar processes.
- Fabricated in high-volume IC foundry to benefit from advanced processing technology.
 - Low cost
 - High yield
 - High performance
- Challenges:
- IC foundry has specific design rules.
- IC foundry not experienced with HV processing.
- Not all processes compatible with HV.

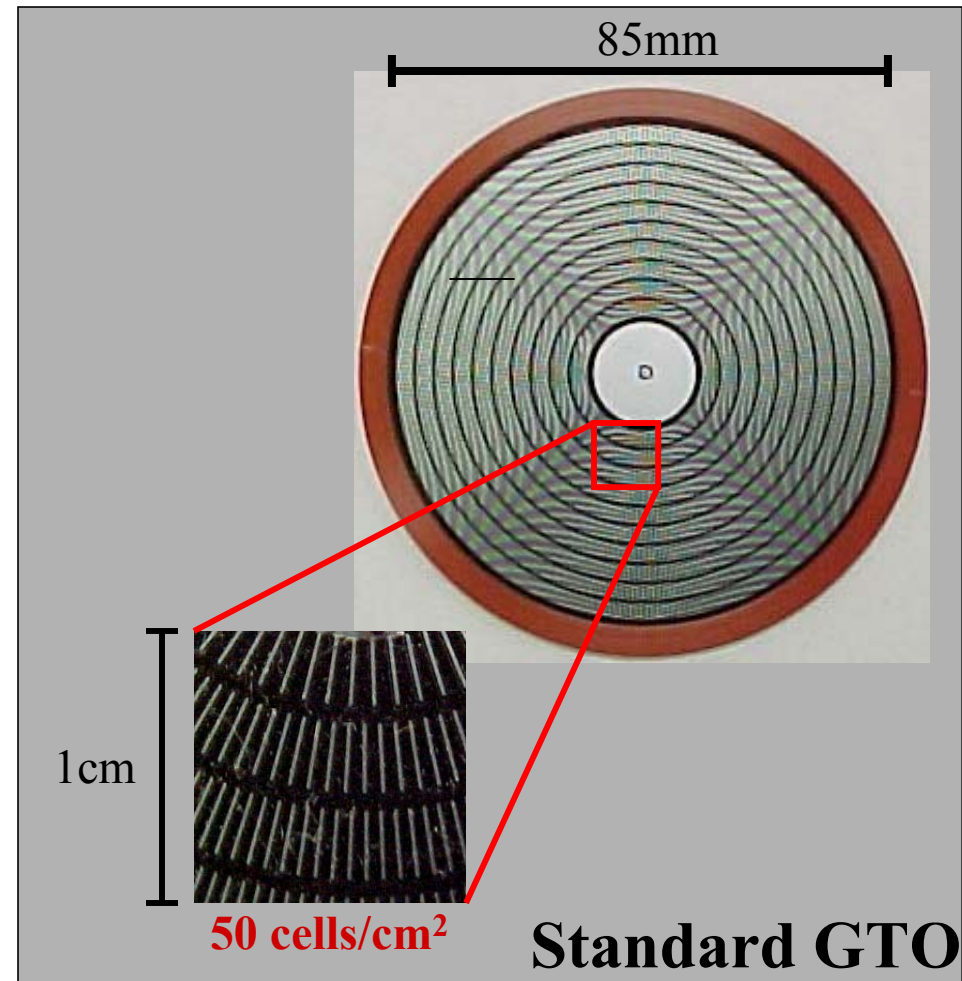
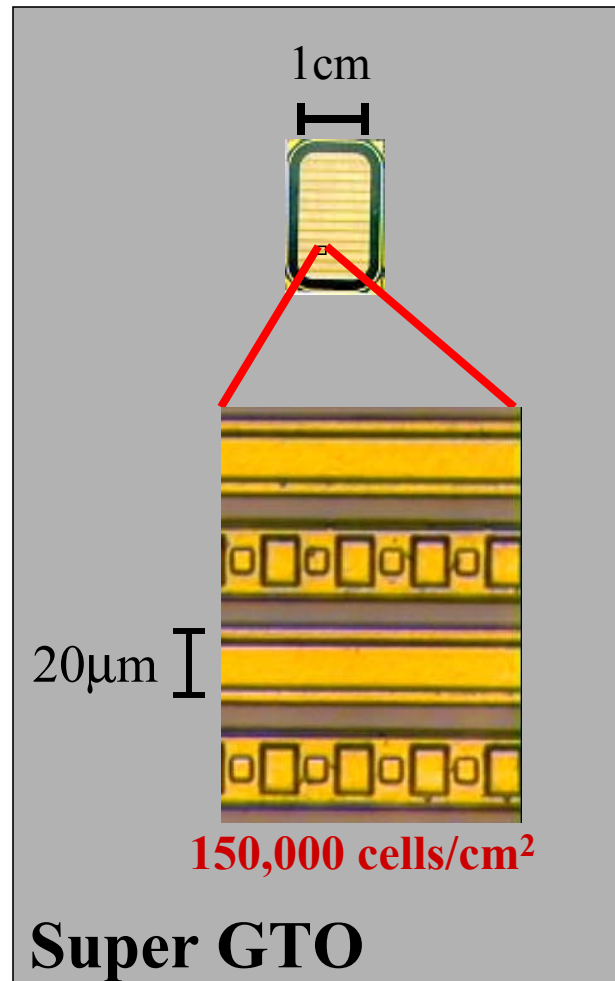
S-GTO vs. Standard GTO



SGTO Advantage

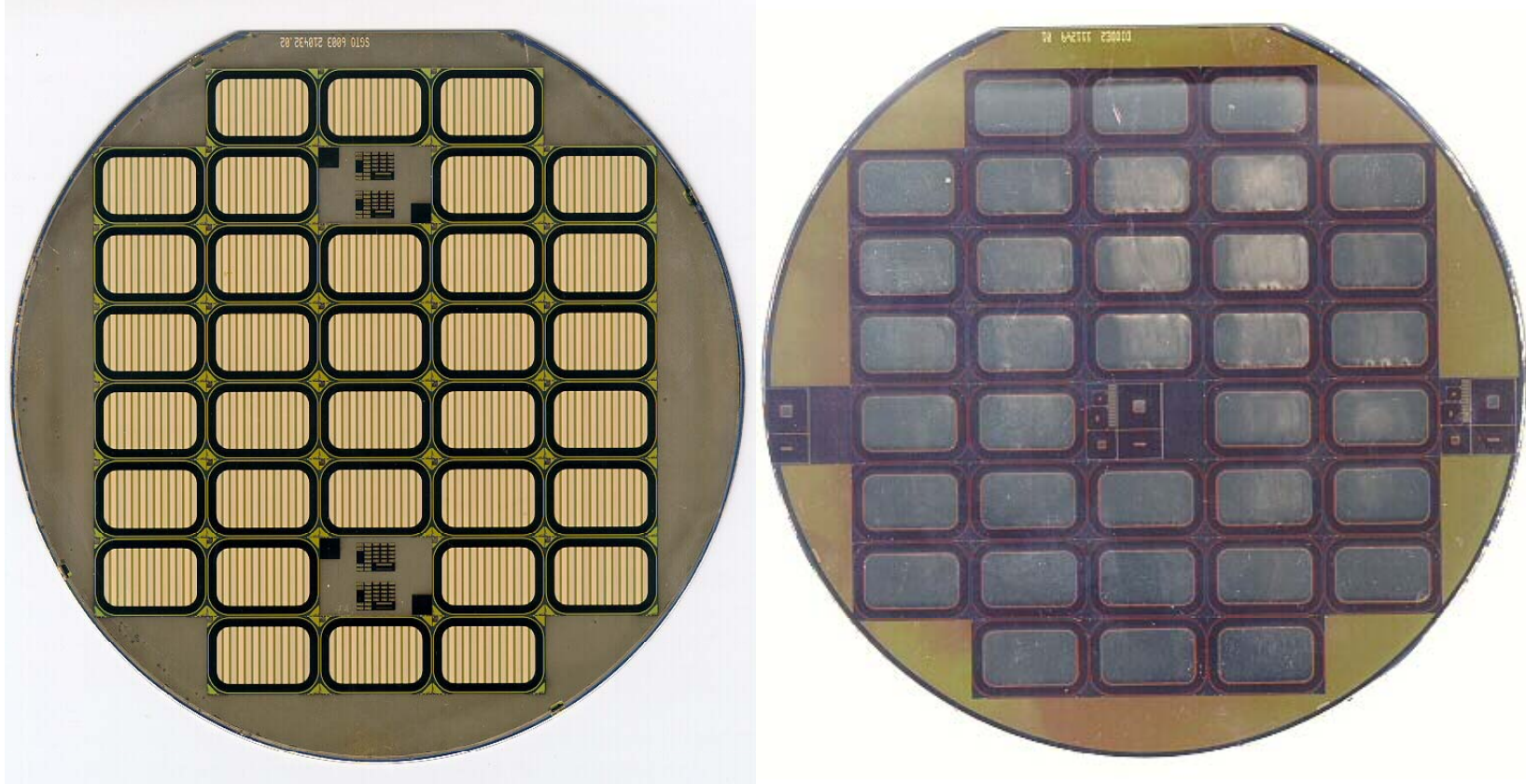
- Shallower base with less charge for higher speed and lower forward drop.
- Narrower cell for 10x higher turn-off capability.

S-GTO vs. Standard GTO



A factor of 3,000 increase in cell density offers a 10-fold increase in turn-off current density.

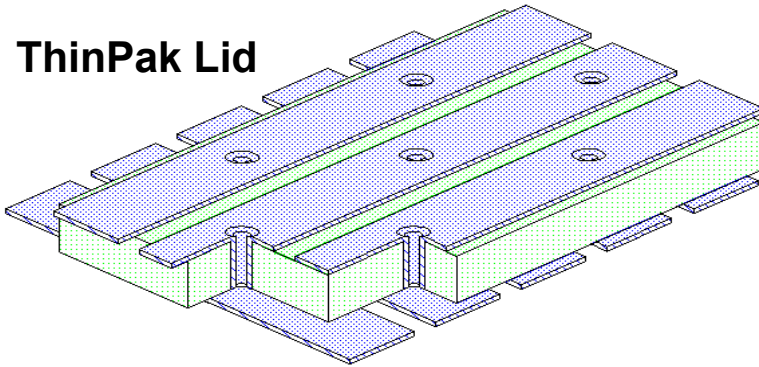
SGTO and S-Diode devices on 6" wafers



**6-inch S-GTO and S-diode wafers processed for
Silicon Power at MICREL**

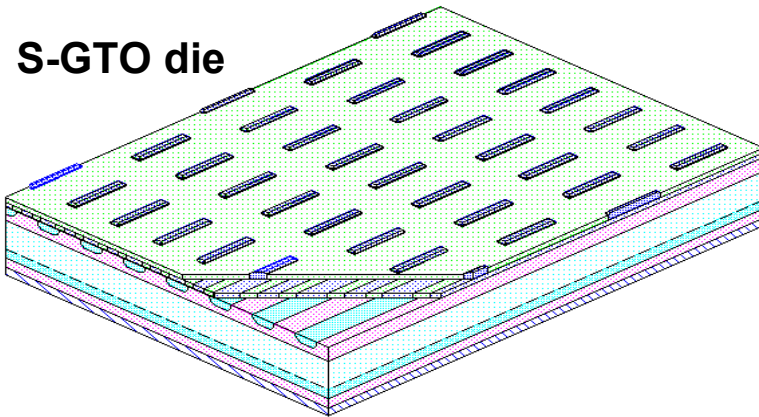
ThinPak Solves GTO Contact and Current Uniformity Problem

ThinPak Lid



ThinPak ceramic lid with connected upper and lower metal layers collect gate and cathode current

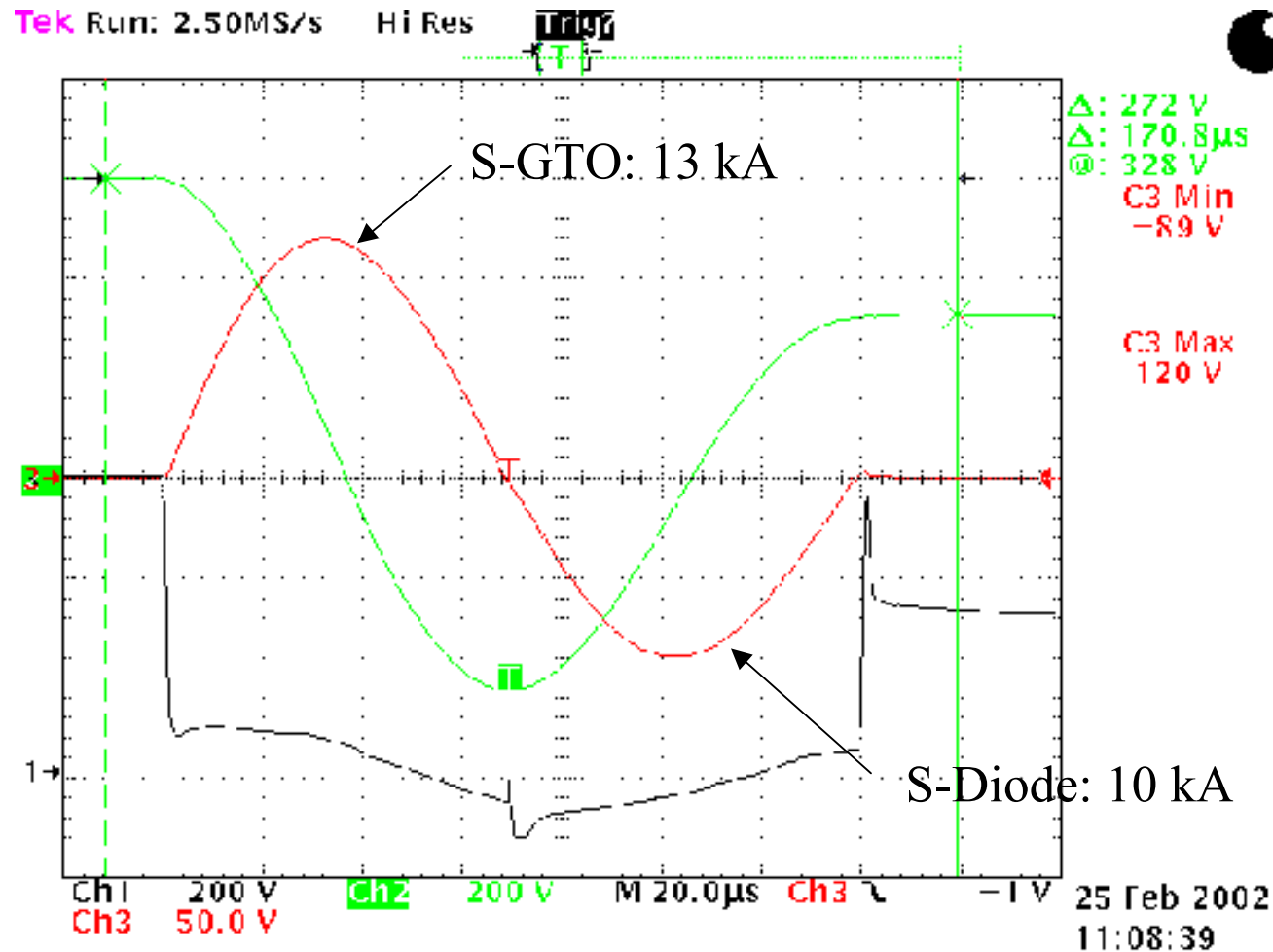
S-GTO die



Two levels of device metal distribute current uniformly to ~320,000 identical cells

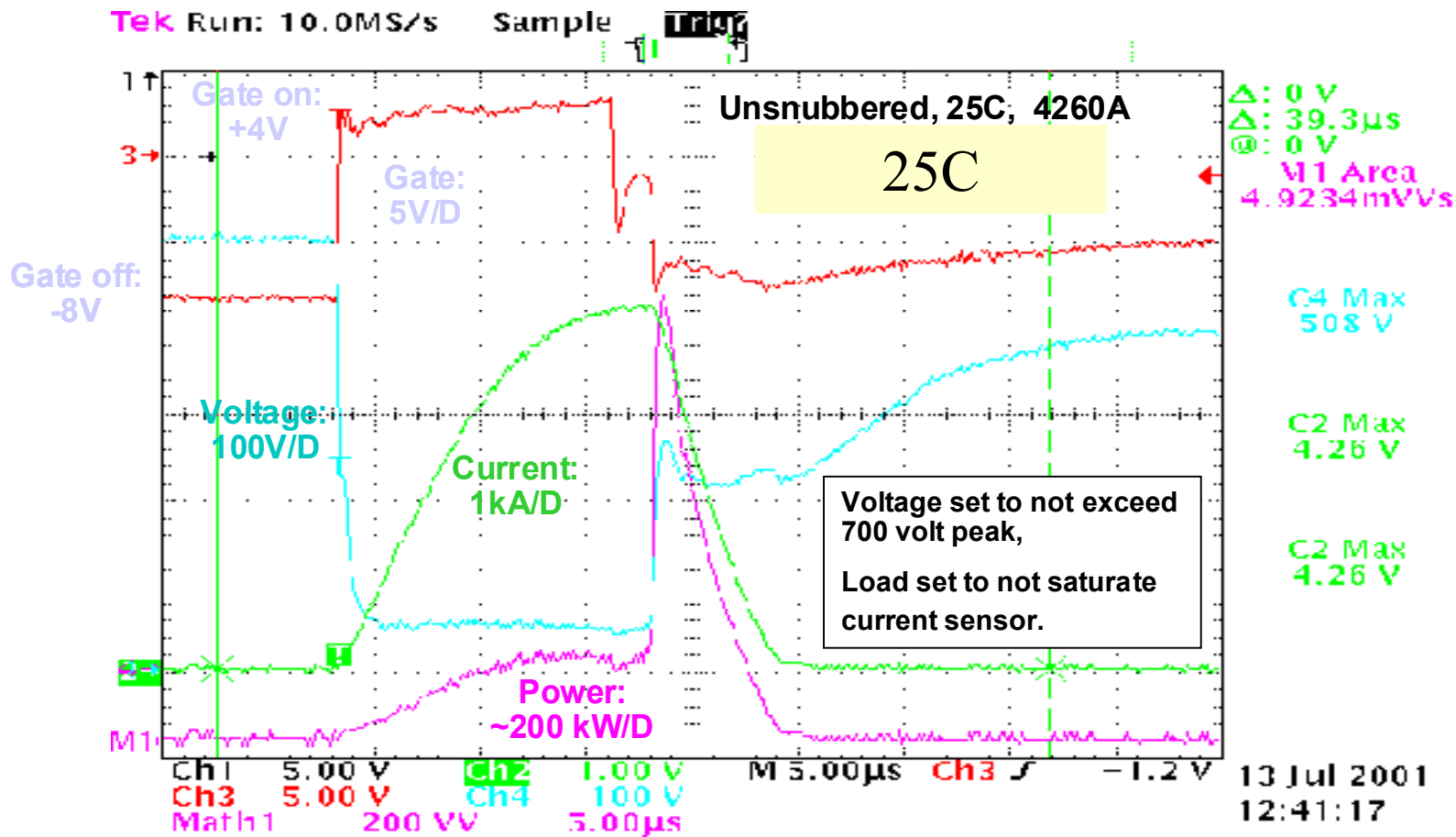
The S-GTO is a combination of a highly interdigitated planar GTO and a thinPak lid of very low and very uniform gate-cathode impedance.

S-GTO / S-diode Pulse Current



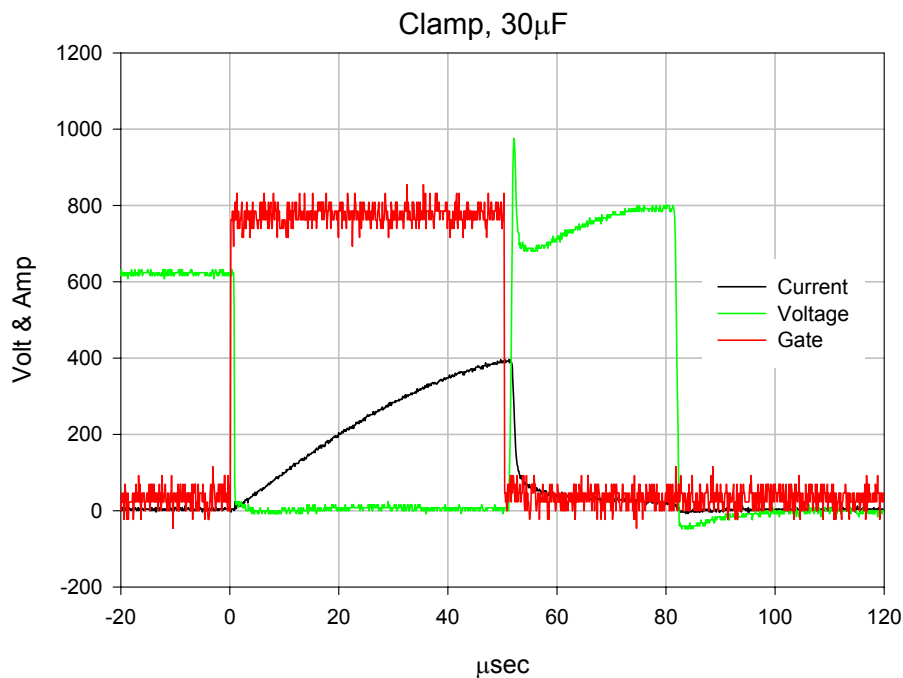
SGTO pulsed at 13 kA (forward current peak) and S-diode at 10 kA (reverse current peak) for 0.1 ms half sine-wave current.

I-off >4000A at Low Voltage at 25 and at 125C

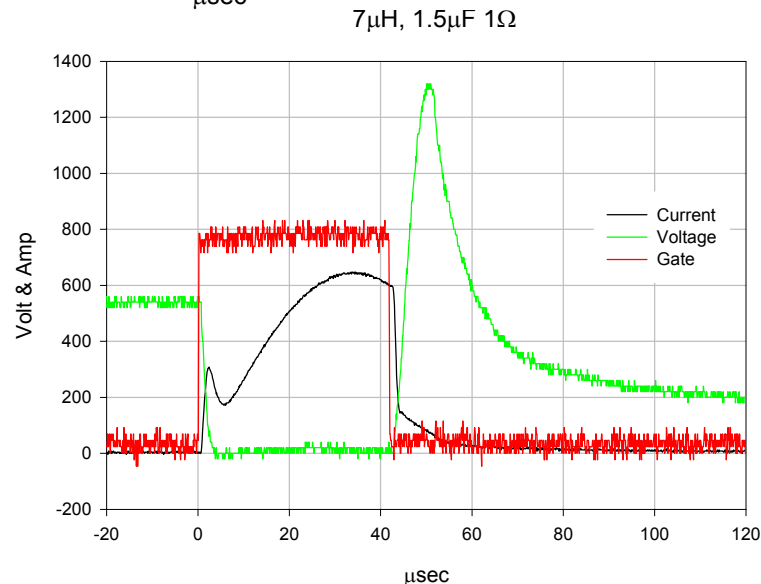
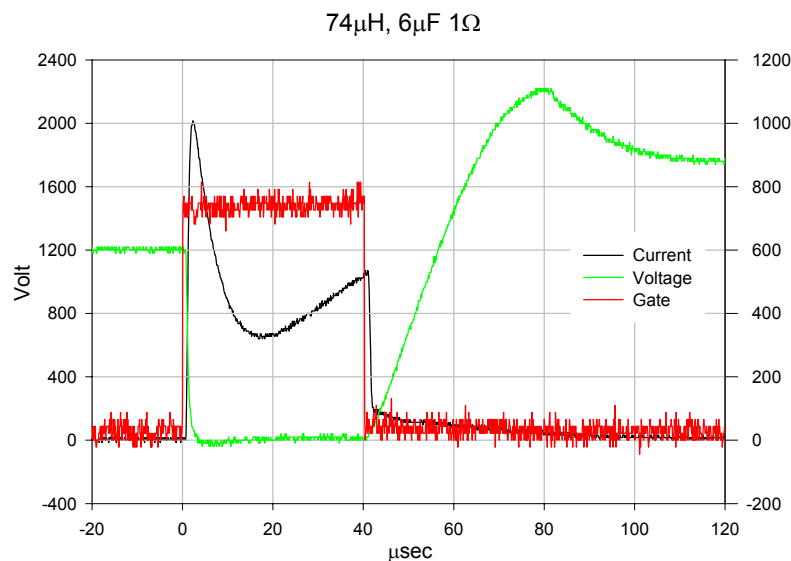


4260A SGTO turn-off at 25C.

S-GTO turn-off at elevated voltage is 1.5 to 2 times better than standard GTO



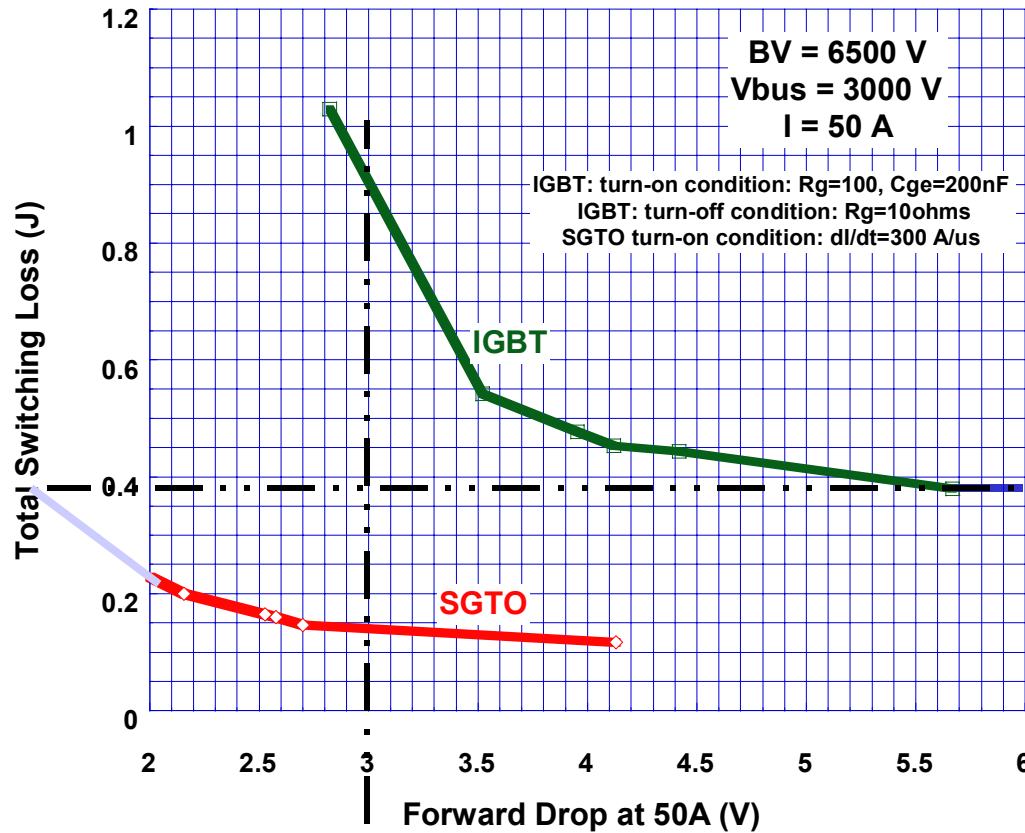
*Unsnubbed
turn-off at
400A, 1000V
peak*



Soft switched turn-off at 500A, 2200V max, left, and 600A, 1320V max, right

Combined Speed and Conduction Trade-off at 50A/cm² Vf and 50A/cm² Turn-off

Total Switching Loss Comparison



Four times lower
forward drop at
the same
switching loss

Seven times lower switching
loss at equal forward drop

Technology trade-off curves for the optimized S-GTO and IGBT.

“Super” GTO Comparison Summary

Characteristic	Standard GTO (including IGCT, EST, etc)	IGBT	Super-GTO
Voltage	1	0.9	1.1
Current Density	1	1	2
Switching Frequency	1	1.5	3
Turn-off Current Density	1	2	10
Weight	1	0.2	<0.1
Size	1	0.2	<0.1
Cost/kW	1	0.8	0.5

These advantages in all aspects of design make the S-GTO
“Super” for a wide variety of applications

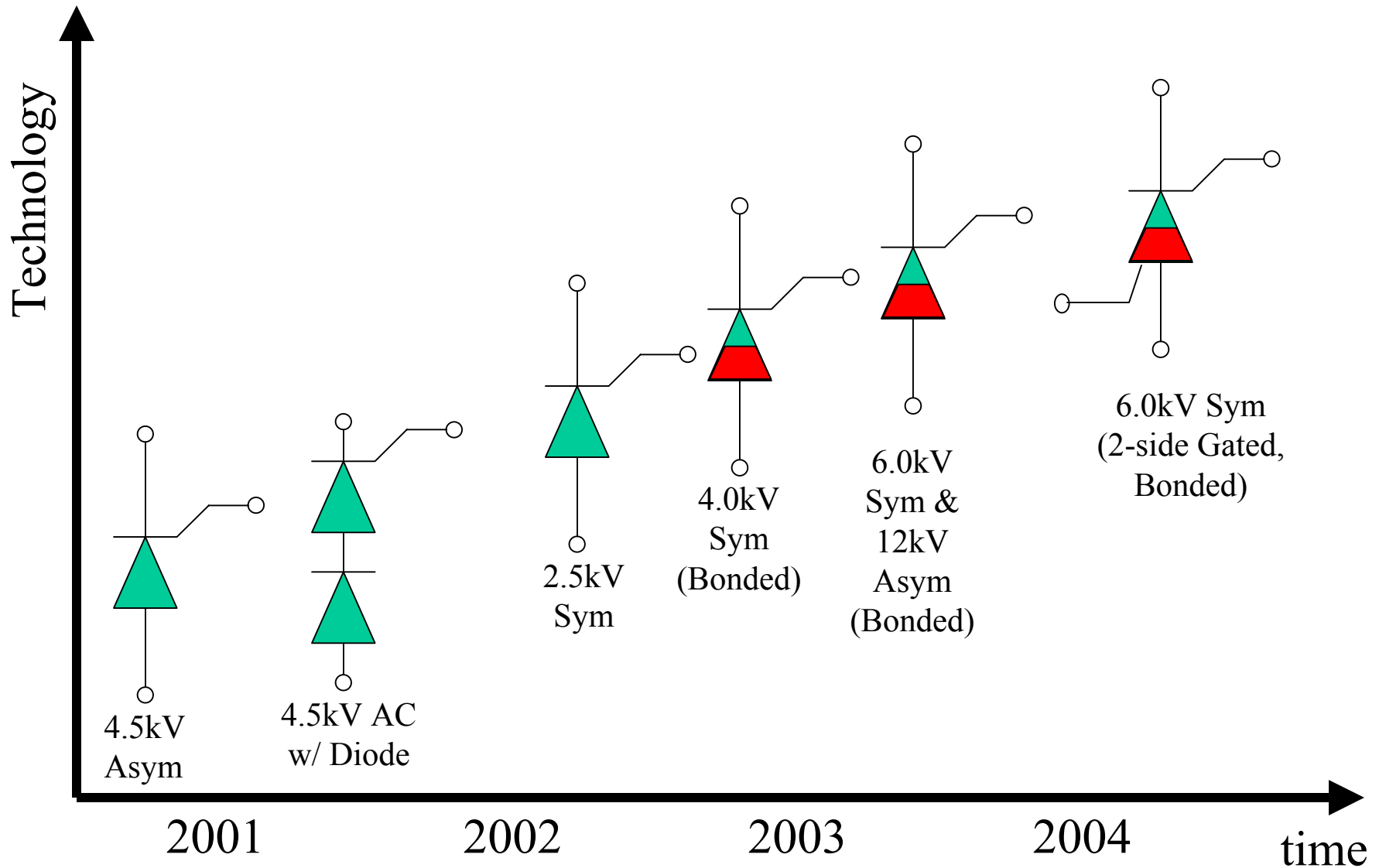
“Super” GTO Comparison Summary for 6KV Ideal (1-D BV) Silicon

Characteristic	Standard GTO (including IGCT)	IGBT	Super-GTO
Rated BV	5 kV	< 5 kV	> 5 kV
Current Density	25A/cm ²	25A/cm ²	50A/cm ²
Switching Frequency	700 Hz	1 kHz	2 kHz
Turn-off Current Density	100A/cm ²	200A/cm ²	500A/ cm ²
Weight (400A)	*1500 gms	600 gms	* 150 gms
Size (400A)	*~1500cc	260 cc	* 100 cc
Est. Cost per KW	* 40c	* 32c	* 20c

* Includes gate drive. Note that GTO clamp hardware is not included.

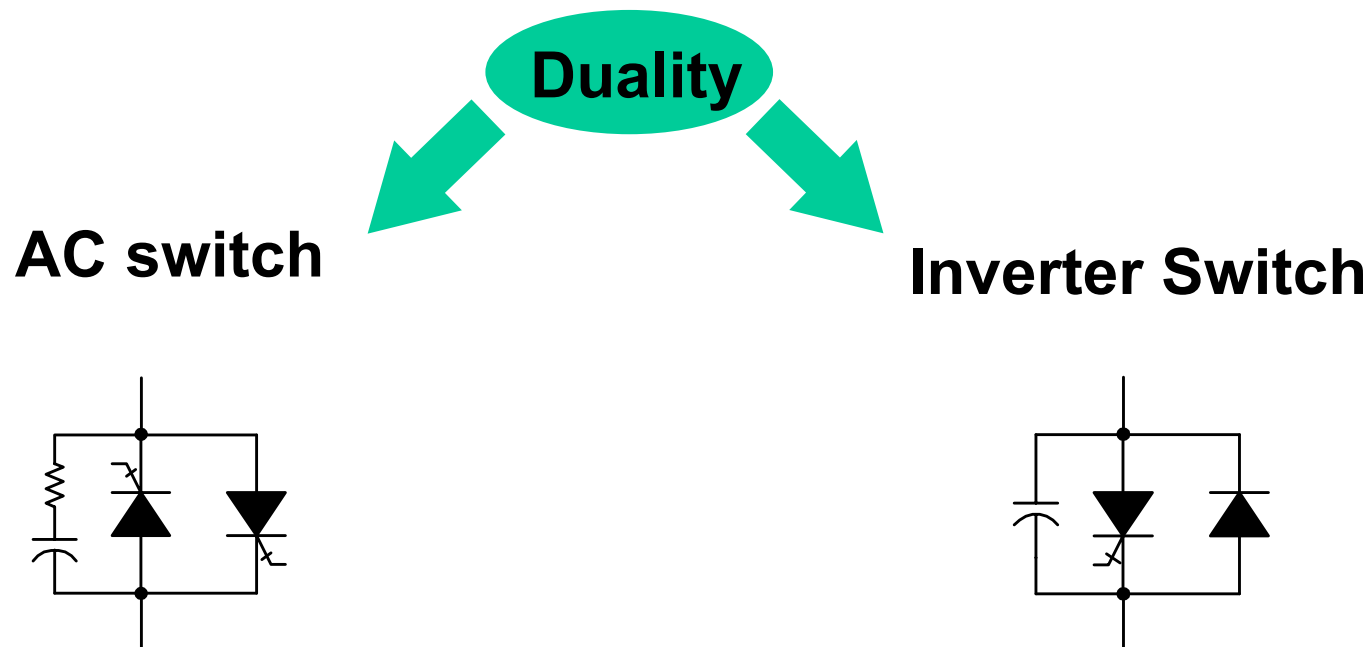
Significant advantages make the S-GTO “Super” for a wide variety of applications

SGTO Roadmap



S-GTO APPLICATIONS

S-GTO Building Blocks



- symmetric blocking
- switch/breaker applications

- zero voltage switching
- asymmetric blocking
- inverter applications

AC SWITCH APPLICATIONS

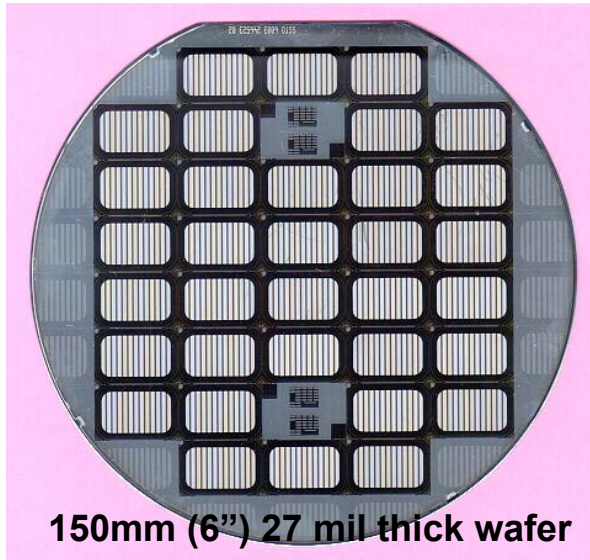


S-GTO AC Switch Module
 $100A_{rms}$, $4500V_{peak}$

Featuring:

- ThinPak packaging
- AlN base unit building block
- Internal gate drive board
- Plug-in control board
- Simple lumped model inclusion for thermal performance prediction
- Thermal cycling capability far in excess of industry standard for traction modules
- Ultra low weight (< 6 Oz) and volume (<12 cubic inches)

SGTO Present Capability: 1-base unit module



IC-fab manufactured, high performance S-GTO on 150 mm wafers – 34 die



Each building block insulated base above mounts two S-GTOs & two S-Diodes

ThinPak for single or multiple die packaging: minimizes volume, weight, cost, maximizes performance.

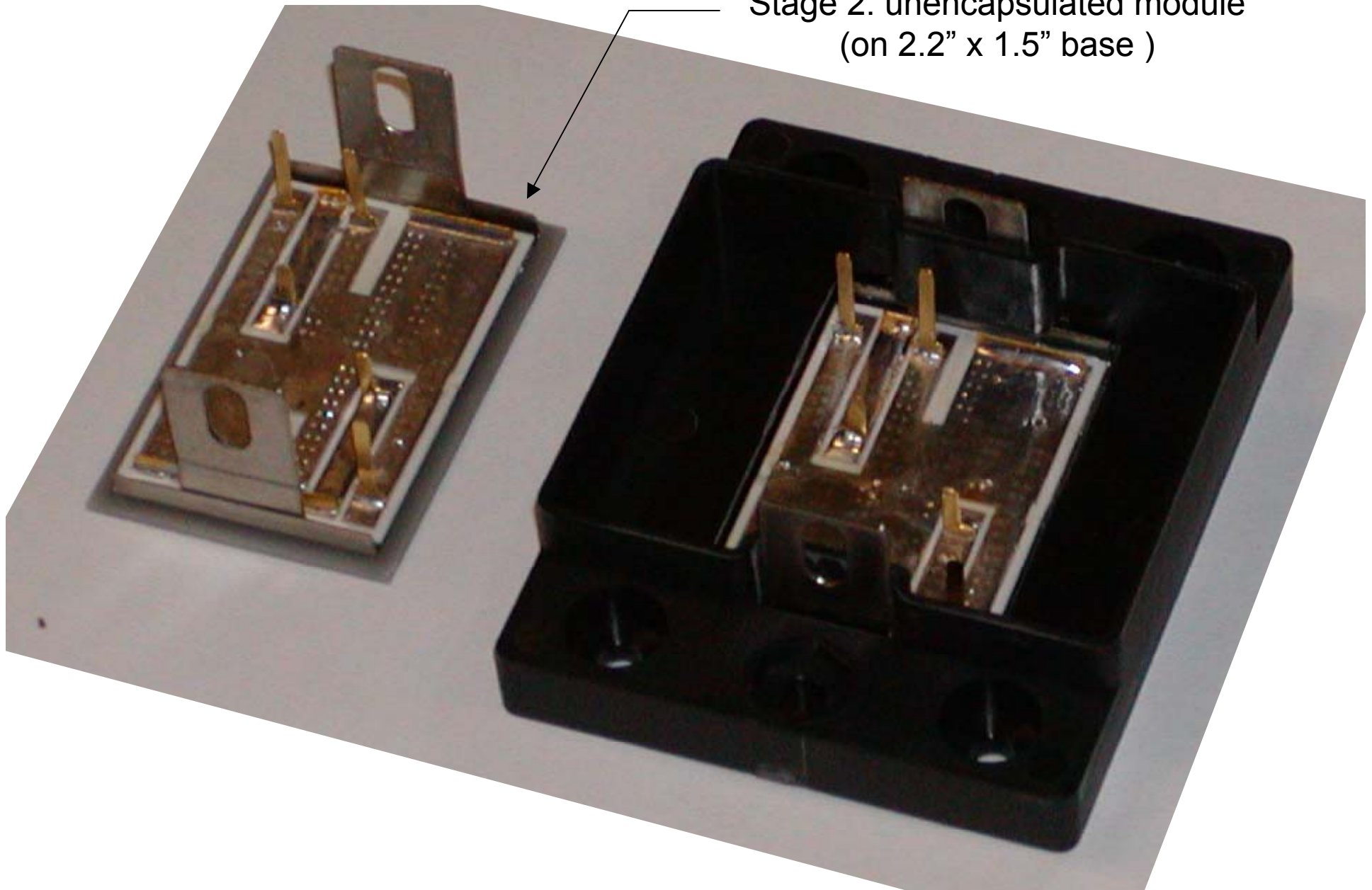


S-GTO die Lid S-GTO after lidding S-MTO with control FET's

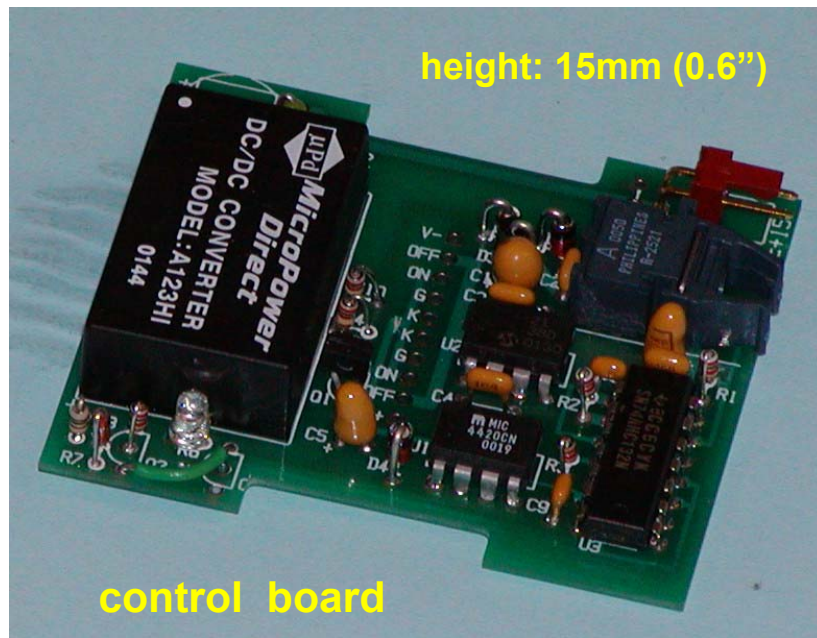


S-GTO thinPak module assembly

Stage 2: unencapsulated module
(on 2.2" x 1.5" base)



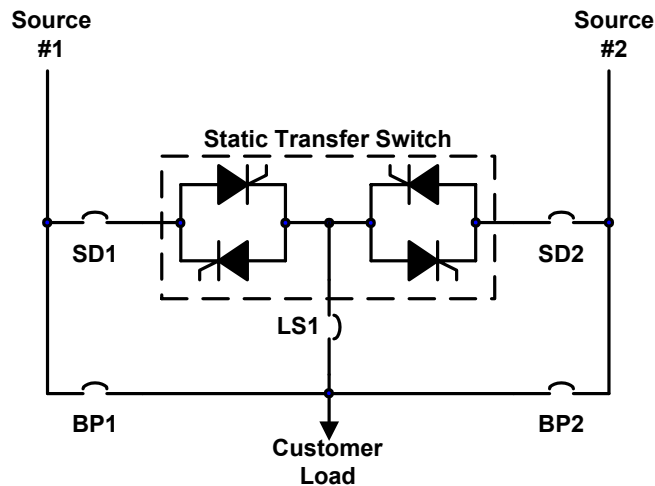
S-GTO thinPak module assembly (cont.)



Note: Modules in this and following slides have been built with two S-diodes and two S-GTO's as an ac switch.



Static Transfer Switch



Typical Static Switch System

- Static ac switches take place of mechanical switches under normal operation
- When voltage sag or outage occurs
 - Gate signal removed from 'primary source' ac switch
 - Gate signal applied to 'alternate source' ac switch
- Switching of sagged/interrupted phase typically takes place within 4 ms.

Subcycle Transfer Switch protects customers with critical loads from:

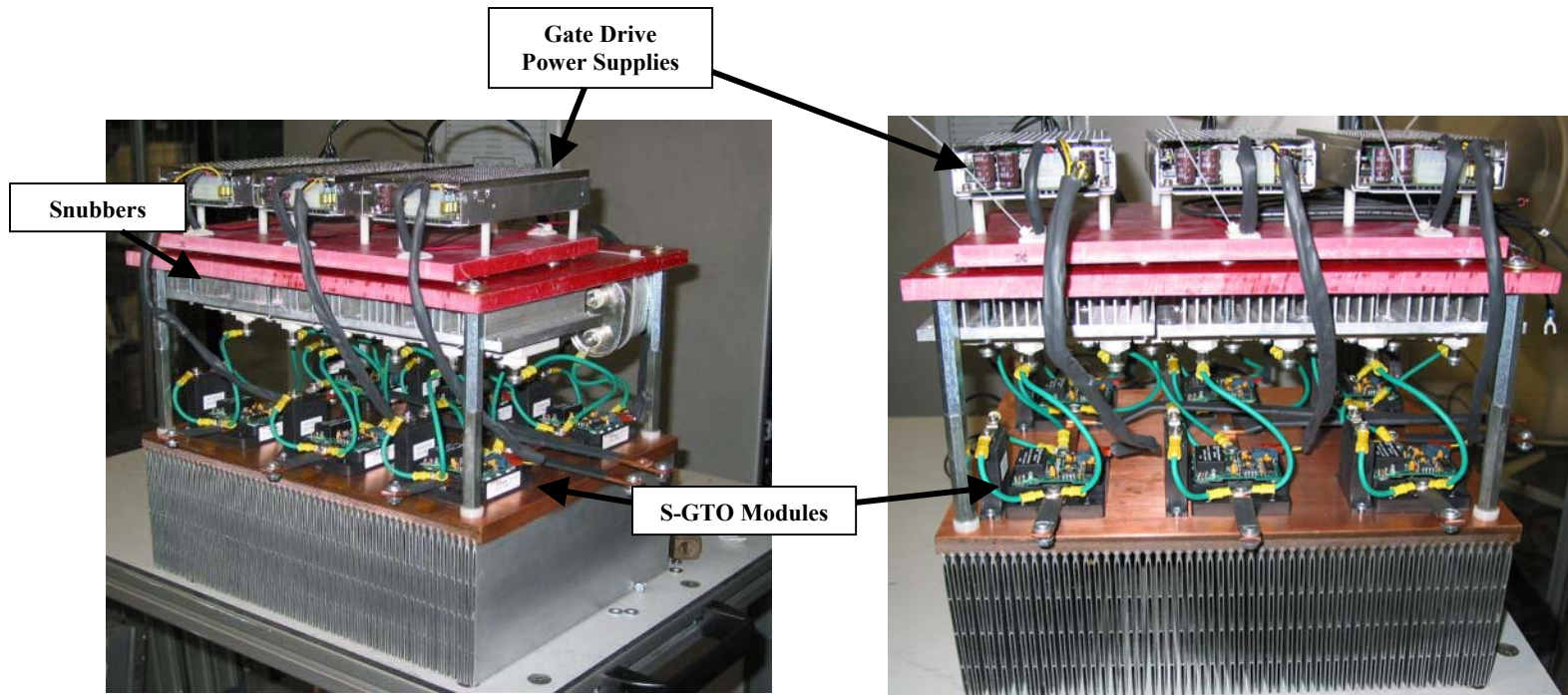
- Outages
- Momentary Interruptions
- Voltage Sags and Swells

Ultra-Fast Transfer Switch

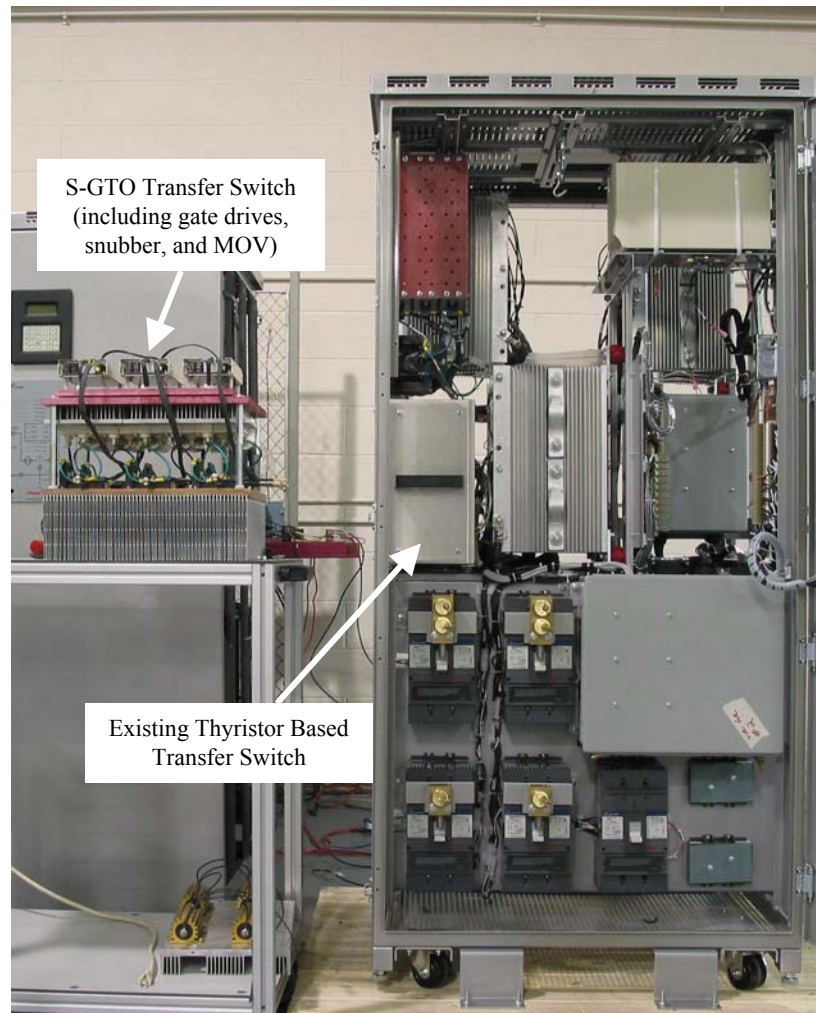
The use of the SGTO gives the Ultra-Fast Transfer Switch (UFTS) the following advantages over existing thyristor transfer switches:

- Faster Transfer Times
 - Transfers in less than 100 μ s (excluding detection time) under any condition
- Fault interrupting capabilities
 - Breakers not needed for fault protection
- More compact than existing thyristor based transfer switches

Close-up view of S-GTO Transfer Switch

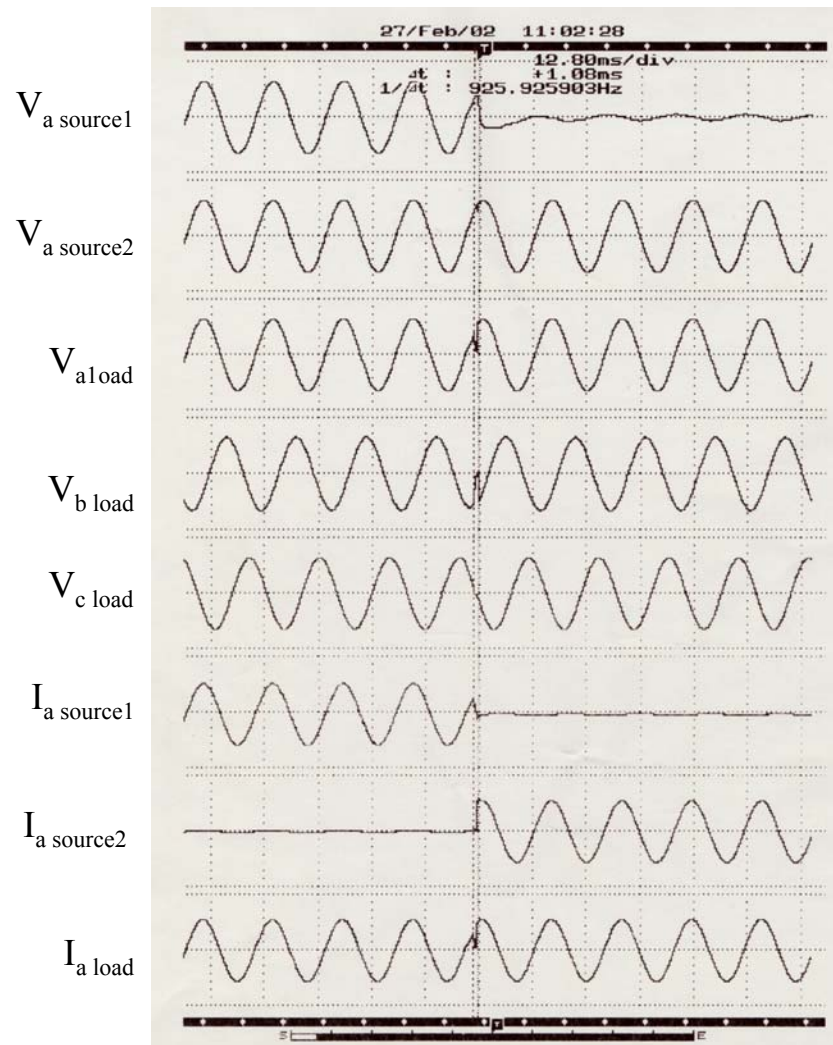


This is a prototype 3-pole unit, no attempt has been made to minimize the footprint and volume.
(~ 20"L x 20"H x 20"D)

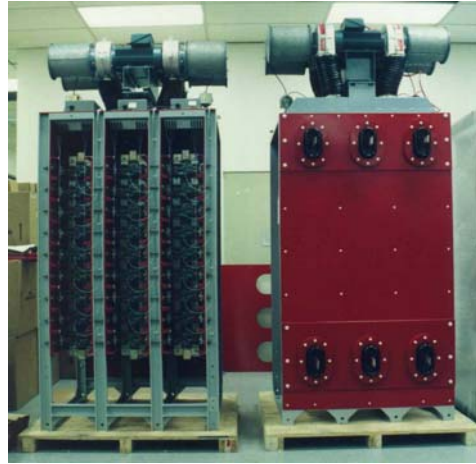


S-GTO Transfer Switch module, (shown left) replaces all components in the top half of the existing thyristor based switch on the right.

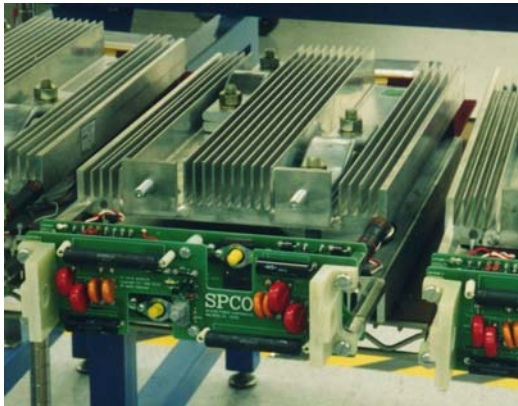
S-GTO Transfer



S-GTO Medium Voltage Subcycle Transfer Switch



15kV, 600A Static Switch
9 – 77mm Thyristor Levels Used/Phase



Replace with

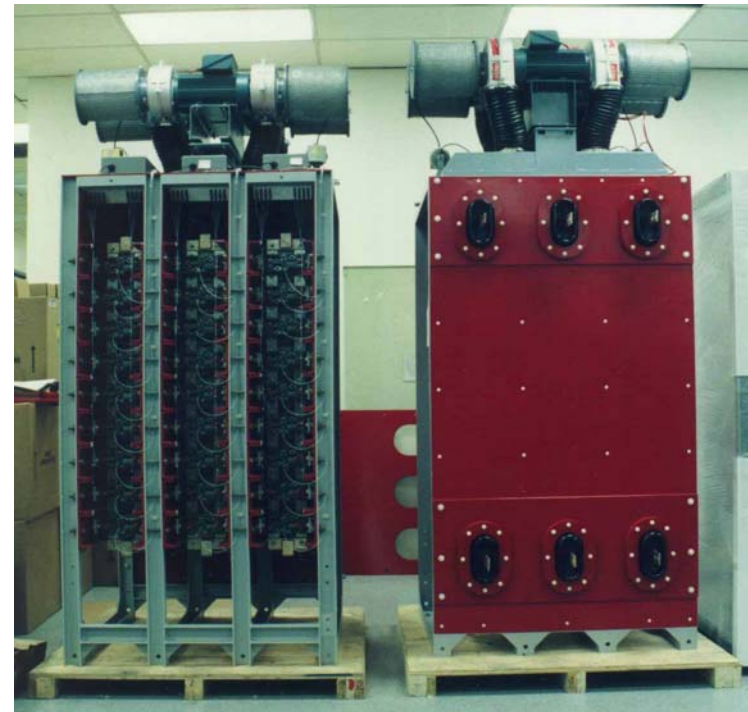


Replaces 2 thyristors and gate drive

S-GTO Medium Voltage Subcycle Transfer Switch

Replacement of conventional thyristors with S-GTO will result in:

- **Smaller Footprint**
(possible padmount unit)
- **Increased performance**
- **Current Limiting Capabilities**
- **30%-40% cost reduction**
(based on 38kV/100A unit)



Capacitor Dynamic Voltage Suppression* (CDVS)

- Utility Capacitor Switching Protection



*Christofersen U.S. Pat No. 6,459,559

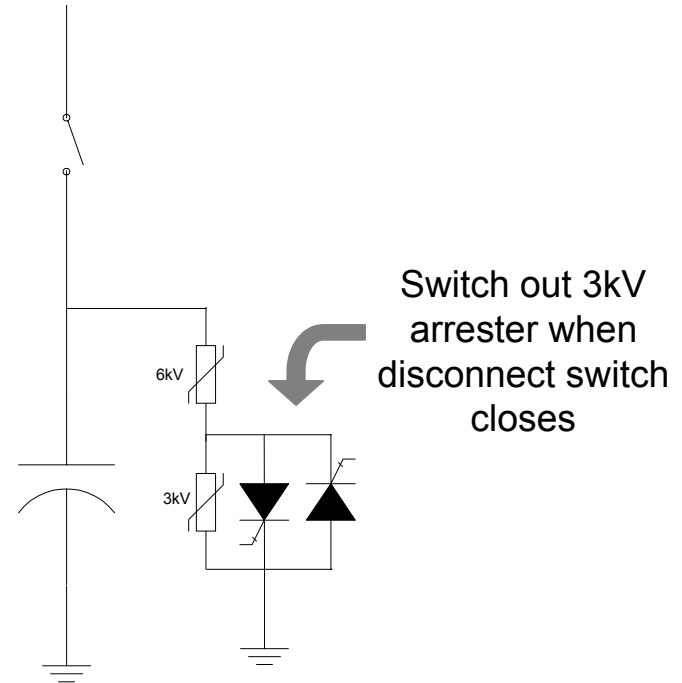
SILICON
 **POWER**

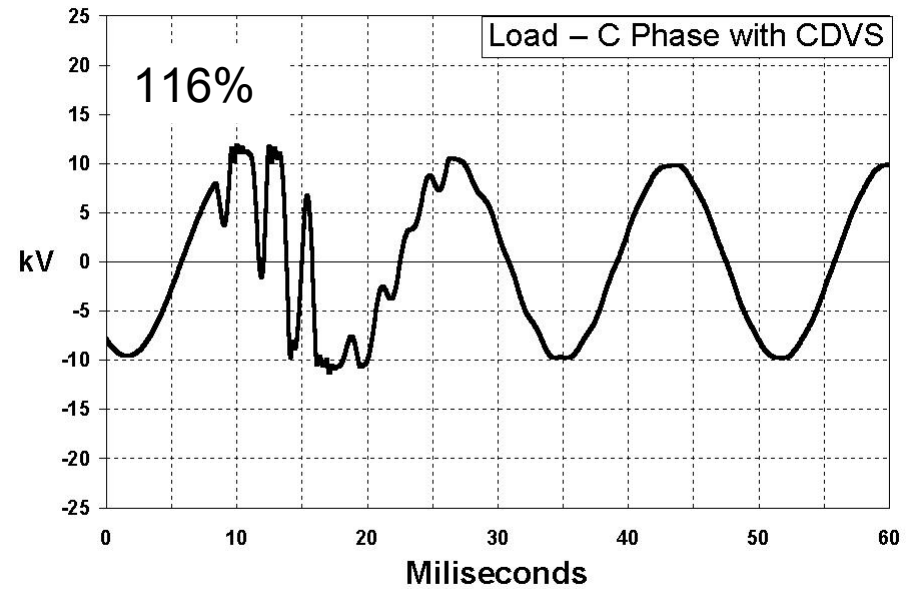
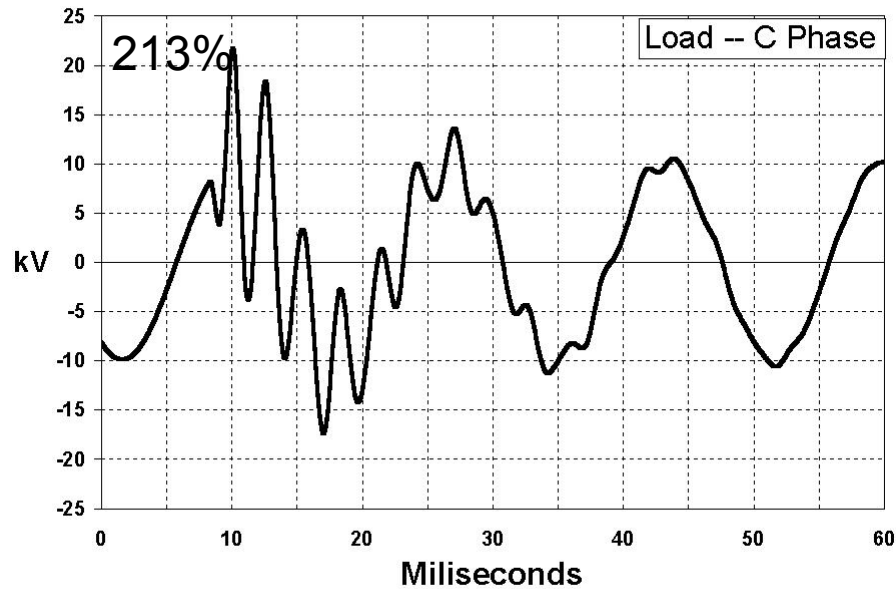
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CDVS Operation

Using switched varistor allows:

- Inrush overvoltage reduction
- Mitigate Voltage magnification
- No need for synchronous closing
- Fast capacitor discharge

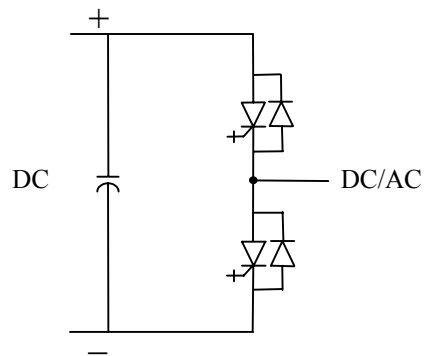
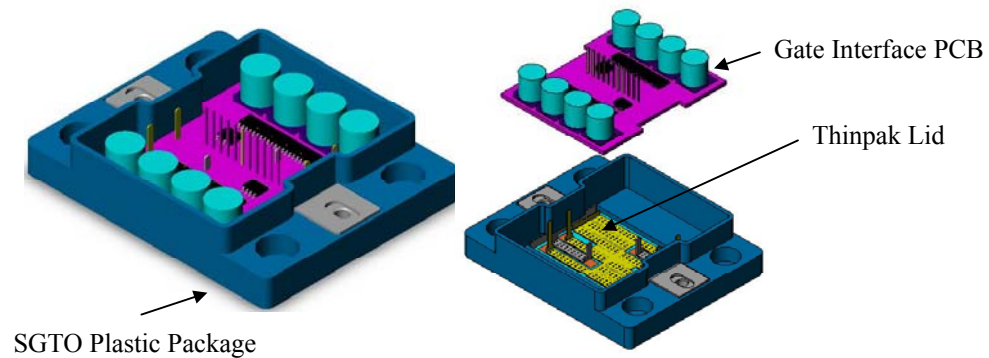




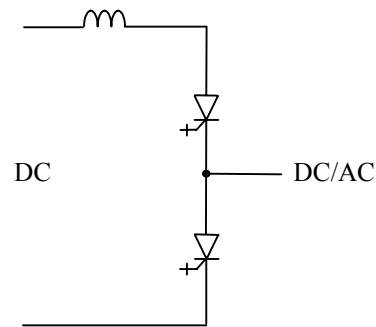
12.47 kV Bus Overvoltage Summary

	A Phase	B Phase	C Phase
Without CDVS	165%	209%	213%
With CDVS	112%	115%	116%

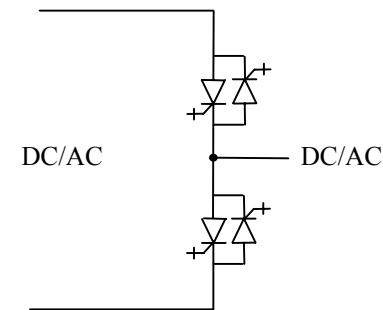
Flexible Packaging for Converter Modules



Voltage Source Converter



Current Source Converter

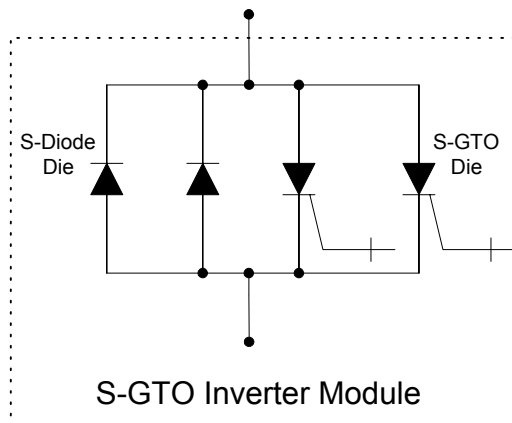


Matrix/ Cyclo-Converter

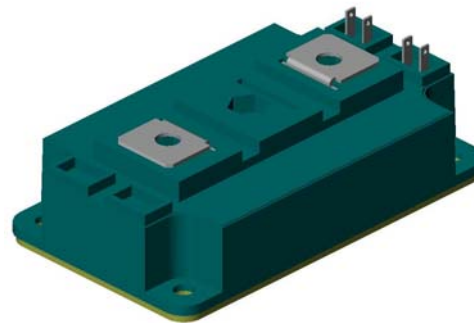
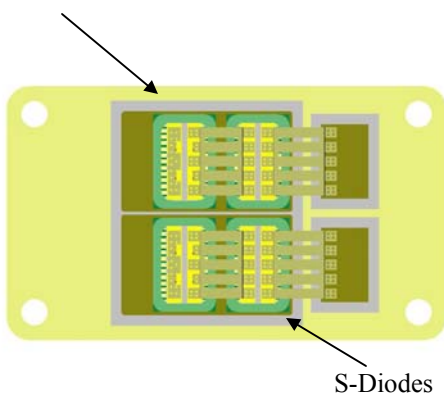
INVERTER SWITCH APPLICATIONS

Inverter Switch Module

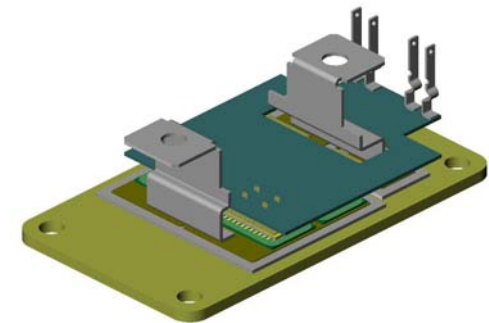
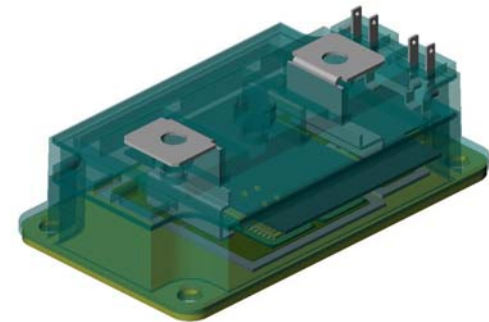
2nd Generation



SGTOs

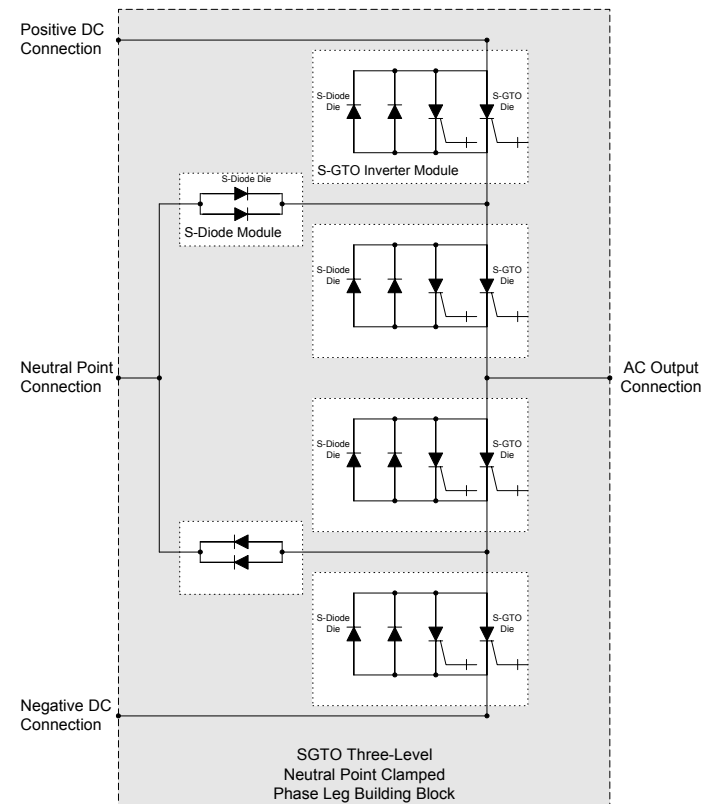


400 A, 5000 V



3-Level NPC Inverter Application

- Uses Asymmetrical S-GTO module
 - Base Module: 400 A, 5 kV
- Scalable to Higher Power Levels

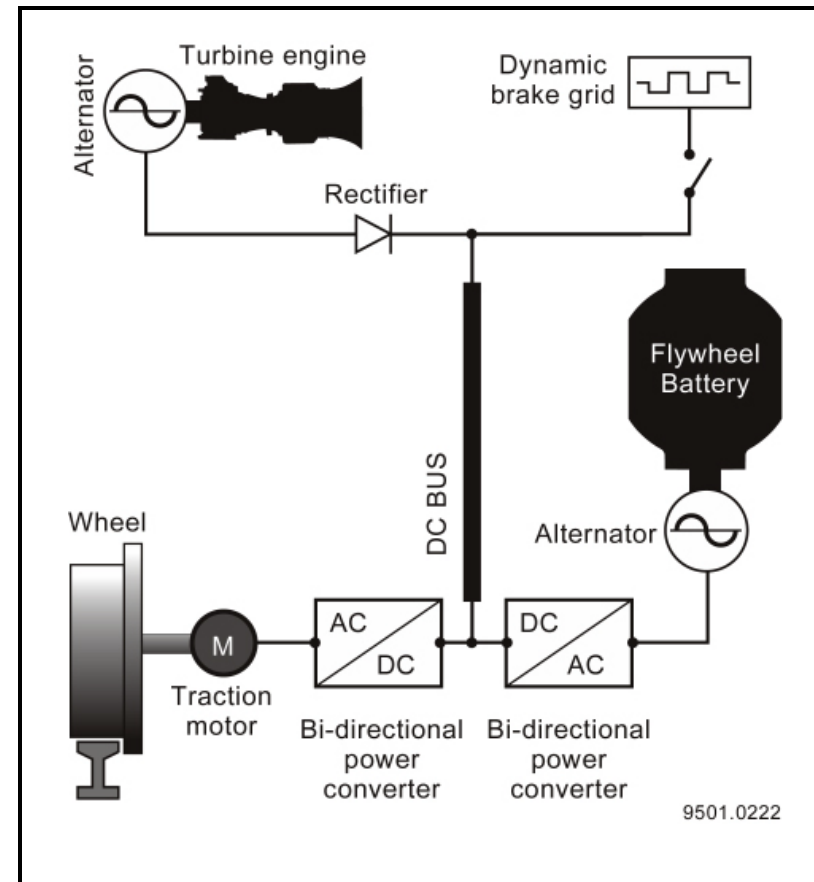


Phase Leg development Project

SGTO Phase Leg Specifications	
Dc link voltage	2500Vdc (max 2800Vdc)
Output voltage	3300Vdc line-line (1905 V l-n)
Output current	1600 Arms
Switching Frequency	750 Hz
Topology	Neutral-point-clamped (3 level)
Control System Interface	HP Versalink gating/diagnostic
Cooling	Water cooled

ALPS System Description

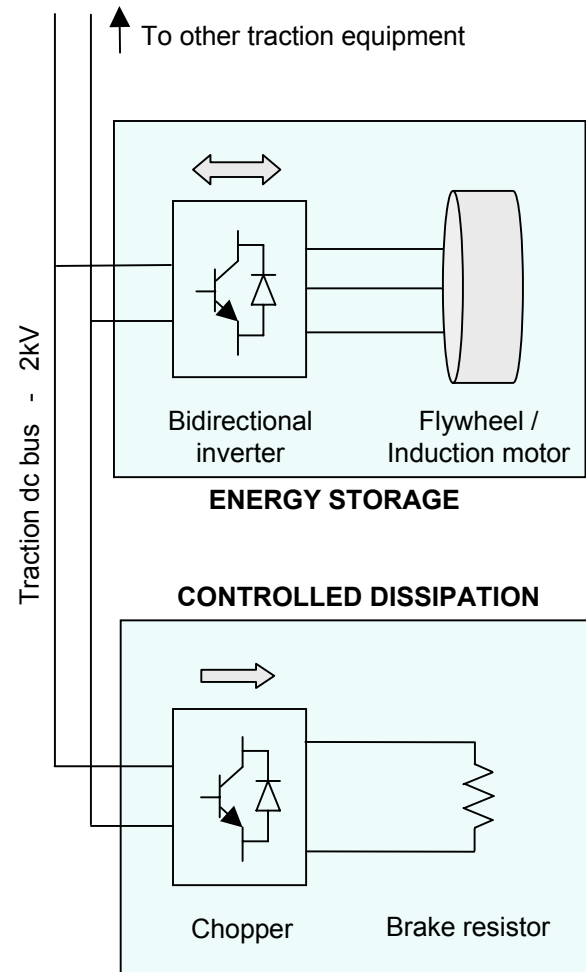
- Turbo-Alternator
 - Overcome rolling resistance
 - Maintain cruising speed
 - Provide hotel power requirements
- Energy Storage Flywheel
 - Supplemental power for acceleration/grade negotiation
 - Recover braking energy
 - Provide load leveling for turbine
- Vendors
 - UT - Flywheel, Program management
 - Honeywell - Turbine Engine
 - Bombardier - Locomotive



ALPS Power Flow Schematic

Silicon Power Scope of Supply

- Inverter
 - High speed flywheel interface (15,000 rpm)
 - High frequency switching for compact motor
 - 2 MW cont., 3.2 MW intermittent rating
 - 2 kV dc; 1150 V, 2200 A ac
- Dynamic Brake
 - Control of traction dc bus voltage
 - Dissipation of excess braking energy
 - Means for emergency shutdown of flywheel
 - 800 A max. braking current

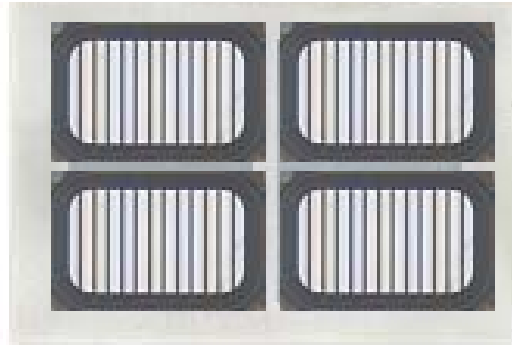


S-GTO FUTURE APPLICATIONS

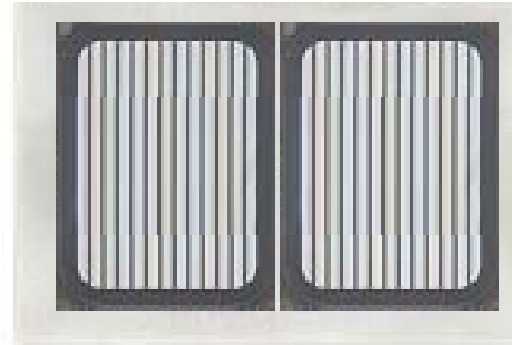
Future Improvement & Applications of S-GTOs

- Increase S-GTO die ratings
 - Larger S-GTO die
 - Produce symmetrical devices
 - Increase blocking voltage > 6kV
 - Increase turn-off capability
- Develop larger S-GTO power blocks

Larger S-GTO Die



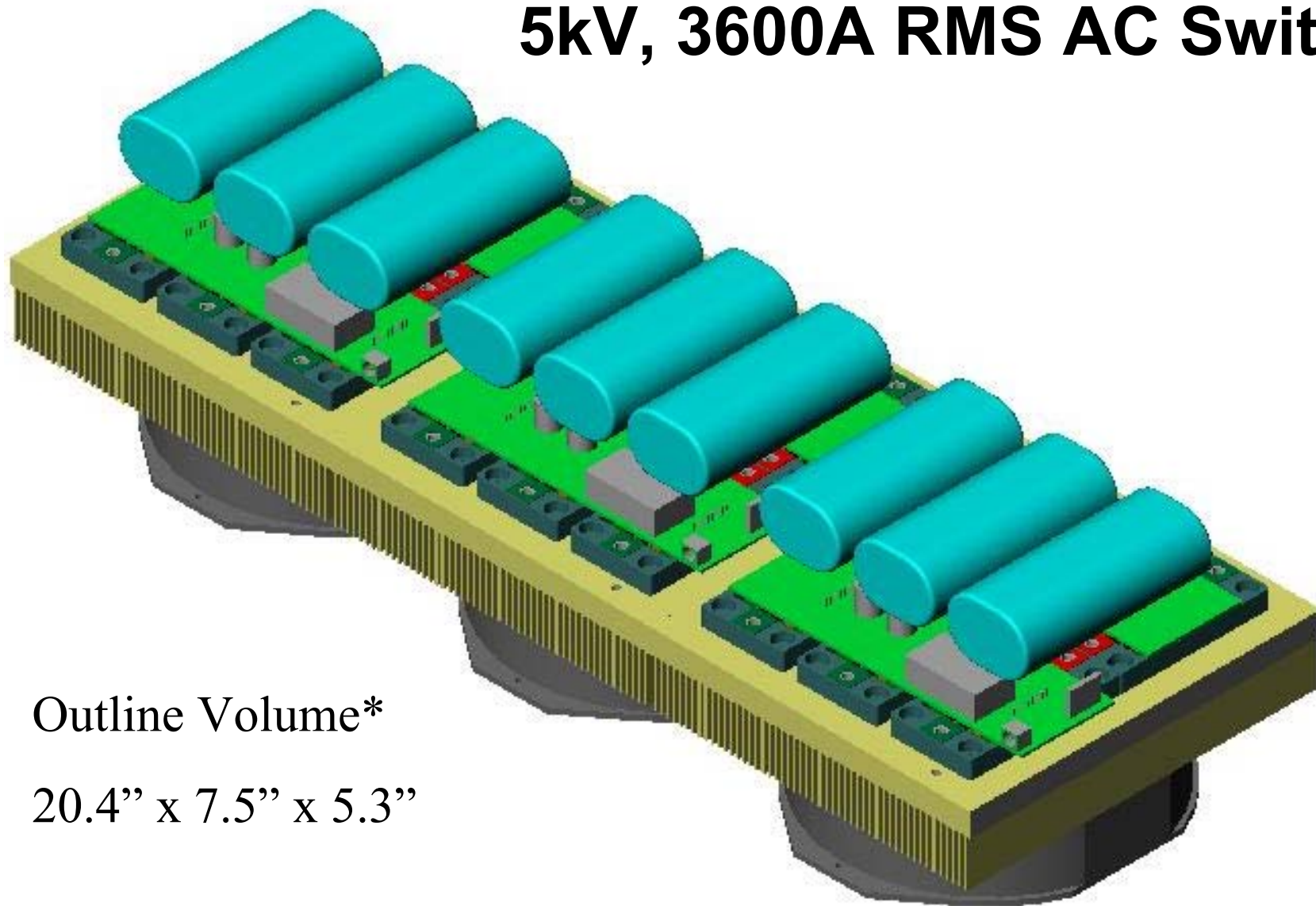
Net Active Silicon: 8.71 cm² (62.5%)



Net Active Silicon: 10.2 cm² (75.3%)

Benefit of larger die on 2.2" x 1.5" AlN substrate:
Fewer module parts, larger module active area

SGTO-Module-Based 3-Phase 5kV, 3600A RMS AC Switch

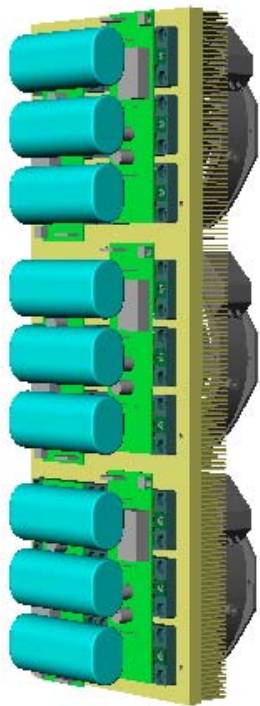


Outline Volume*

20.4" x 7.5" x 5.3"

* This includes gate drives and control as well as snubbers and cooling.

Comparison of Standard and SGTO- Based Switch Design

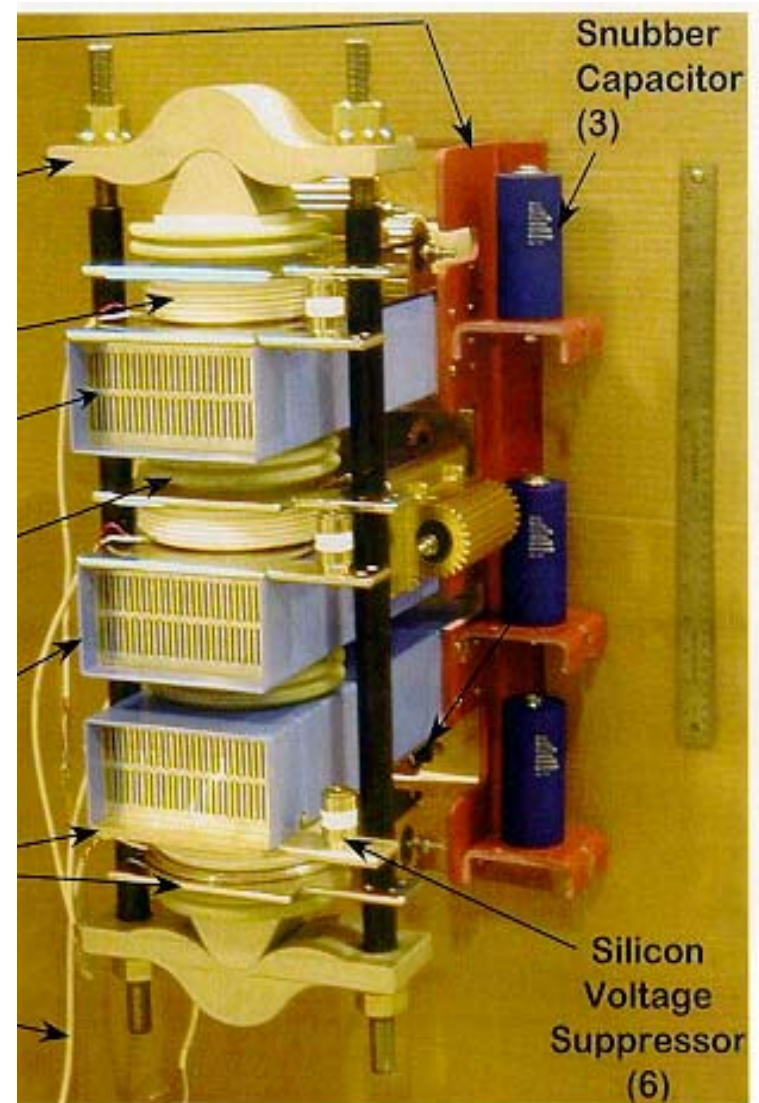


*SGTO-Based
Outline Volume :
6" x 21" x 8"
(1010 cu in)*

*includes gate
drives, controls
and cooling fans*

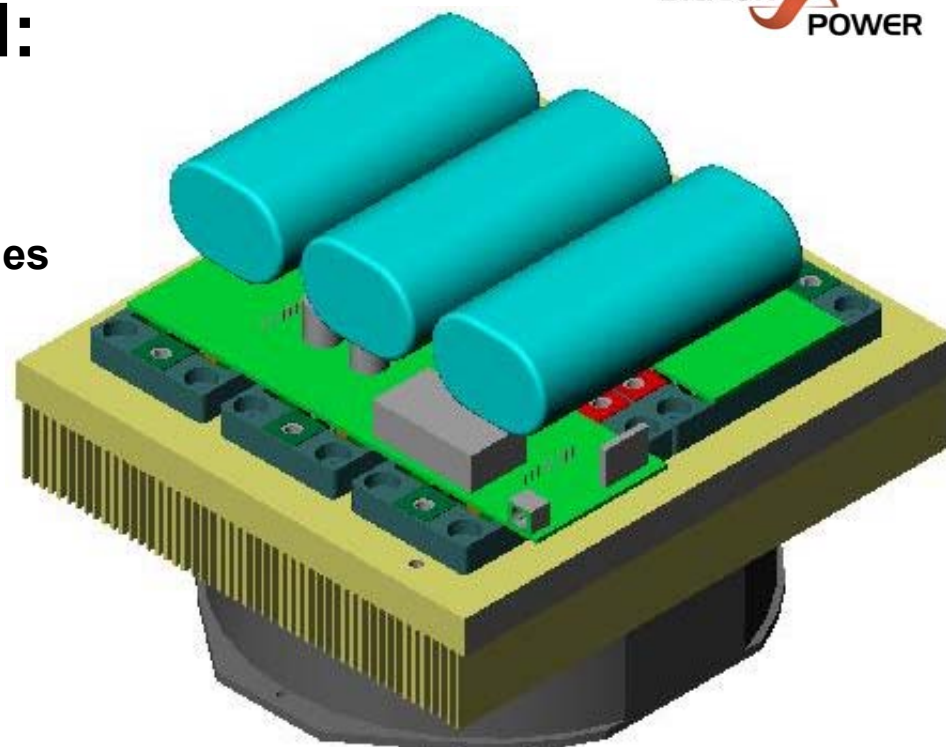
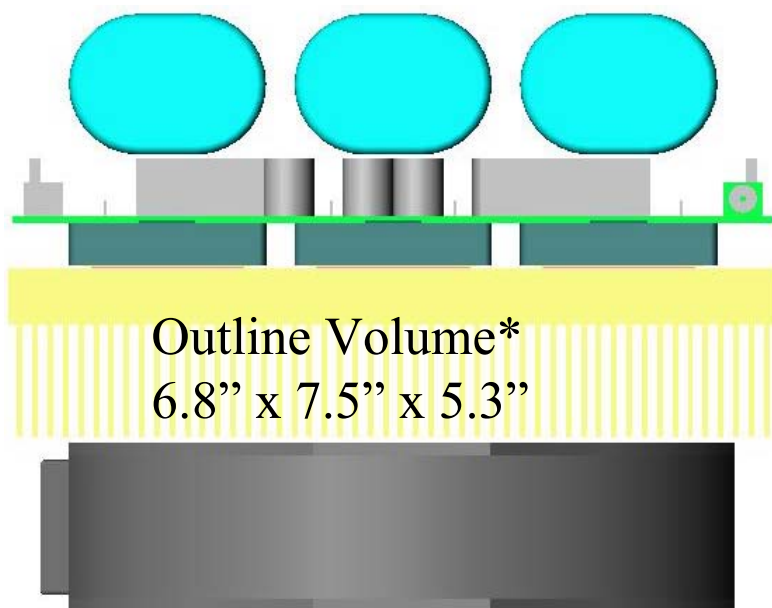
*Bonus: Half the
net losses*

*Standard SCR: Outline Volume :
29.5" x 18" x 14.5" (7700 cu in)
without fans, gate drives, controls*



Single Phase Block BOM:

- 6 single switch SGTO modules with built in gate drive amplifier
- 2 control boards with floating power supplies
- 1/3 of heat sink
- 3 snubber capacitors (minimizes L_{stray})



* One third (6.8") single phase building block forms a complete unit